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13. ABSTRACT (Maximum 200 words) Over the past two years, we significant progressed in analyzing the feedback control algorithm mathematically for a single longitudinal mode, wide aperture semiconductor laser. External delayed optical feedback introduces a large number of extraneous longitudinal modes of the extended cavity. By adjusting feedback parameters, the number of active modes in the transient evolution to the final control state could be controlled. We now have a solid understanding of how the simultaneous spatial and spectral filtering mechanism works. In particular recent works using only time delay spatially homogeneous feedback or spatially shifted feedback can be demonstrated to be of very limited utility. <p style="text-align: center;">DTIC QUALITY INSPECTED 4</p> <p style="text-align: center; font-size: 2em;">20001127 029</p>					
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Final Report
1 Sept 97 to Sept 98
F49620-95-1-0454

Modelling Novel Wavelength and Ultra-Short time-Scale Phenomena in Nonlinear Optics

Arizona Center for Mathematical Sciences
Department of Mathematics
University of Arizona
PI: J. V. Moloney

The Arizona Center for Mathematical Sciences is currently involved in two investigations that are funded by AFOSR. One of these involves the study of ultrashort laser pulse propagation. The other involves modelling the complex dynamics of semiconductor amplifiers and lasers. Both of these projects involving large scale computation utilizing an in-house dedicated computational facility funded under a DURIP award and remote DOD supercomputing sites. This AASERT award was in support of the contract AFOSR-F49620-97-1-0002, "High Speed Modulation, Beam Steering and Control of Spatiotemporal Chaos in Semiconductor Lasers."

David Hochheiser, who was the recipient of this award continued his work on two large scale computational projects. The first, involving the study of spatiotemporal evolution of nonlinear coherent structures in a mathematically stiff two-level laser has made very significant progress over the past two years. A nonlinear control strategy has been developed which both locks in an orbit of the turbulent laser output and steers the output as desired. (See Reference 2.) The paper [D. Hochheiser, I. Aranson and J.V. Moloney, "Boundary Induced Pattern Selection in Large Aspect Ratio lasers,"] has recently appeared in *Physical Review A*. (See Reference 1.) An interactive simulation of the complex semiconductor laser Swift-Hohenberg pde coupled to a mean flow has been implemented by David using the AVS graphics package. This allows interactive dialing of problem parameters (coefficients of the nonlinear pde's) as the solution evolves in space-time. The second project involved the implementation of efficient outgoing wave boundary conditions in nonlinear vector Maxwell solvers. A number of schemes have been tried and the "perfectly matched layer" method is most promising. This code is being successfully applied to 1D and 2D layered nonlinear homogeneous, absorbing and grating structures and spurious reflections from the computational boundaries have been minimized. The vector Maxwell code is being extensively used by various members of the ACMS research group to study novel nonlinear electromagnetic propagation effects.

Over the past two years, David made significant progress in analyzing the feedback control algorithm mathematically for a single longitudinal mode, wide aperture semiconductor laser. External delayed optical feedback introduces a large number of extraneous longitudinal modes of the extended cavity. By adjusting feedback parameters, the number of active modes in the transient evolution to the final control state could be controlled. We now have a solid understanding of how the simultaneous spatial and spectral filtering mechanism works. In particular recent works using only time delay spatially homogeneous feedback or spatially shifted feedback can be demonstrated to be of very limited utility.

The control scheme was extended to 2D single-longitudinal mode surface emitting semiconductor lasers. This configuration allowed much greater flexibility in the choice of spatial filter. We demonstrated control of off-axis uniform and various patterned illuminations.

We were able to verify the 1D control of the semiconductor CSH equation for solving our full nonlinear pde model for comparison. In the latter we shortened the cavity to restrict the spatiotemporal dynamics to a single longitudinal mode and introduced realistic individual facet reflectivities at both ends of the laser and in the external feedback loop. The control worked for this case, also, which is extremely encouraging.

Part of the funds in the AASERT were deployed to initiate an undergraduate research experience project. Four U.S. undergraduates, Robert Thompson (sophomore), Leon Lin (Senior), Adam Arluke (Senior), and T. Cadwallader (Senior) were partially supported over two semesters. The students were exposed to research problems in nonlinear optics and learned to apply dynamical systems tools to laser dynamics. The interactions involved specialized lectures by Math faculty (Moloney, Ercolani, Lega, Hsu), faculty and graduate student supervisor (J.K. White, a graduate student supported under an AASERT award), and seminar presentations by the students to the faculty. The goal of this effort was to expose the students to research level problems at a stage in their studies where they are about to decide on a future career and allow them to see how classroom learned materials are utilized on real problems.

References:

1. D. Hochheiser, I. Aranson, and J. V. Moloney "Boundary-Driven Selection of Patterns in Large-Aspect-Ratio Lasers," *Physical Review A*, **55** #4, pp.3173-3176, April 1997.
2. D. Hochheiser, J. V. Moloney, and J. Lega "Controlling Optical Turbulence," *Physical Review A*, **55** #6, pp. 4011-4014, June 1997.
3. M.E. Bleich, D. Hochheiser, J.V. Moloney, and J.E.S. Socolar, "Controlling Extended Systems with Spatially Filtered, Time-Delayed Feedback," *Physical Review E*, **55**, pp. 2119, 1996.
4. J.V. Moloney, "Coherent Structures in Dissipative Nonlinear Optical Systems," Springer Book, *Nonlinear Science at the Dawn of the 21th Century* (1999).

AUGMENTATION AWARDS FOR SCIENCE & ENGINEERING RESEARCH TRAINING (AASERT)
REPORTING FORM

The Department of Defense (DoD) requires certain information to evaluate the effectiveness of the AASERT program. By accepting this Grant which bestows the AASERT funds, the Grantee agrees to provide 1) a brief (not to exceed one page) narrative technical report of the research training activities of the AASERT-funded student(s) and 2) the information should be provided to the Government's technical point of contact by each annual anniversary of the AASERT award date.

1. Grantee identification data: (R&T and Grant numbers found on Page 1 of Grant)

- a. University of Arizona (FRS 310500)
University Name
- b. F49620-95-1-0454
Grant Number
- c. _____
R&T Number
- d. J. V. Moloney
P.I. Name
- e. From: 1 Sept 97 To: 1 Sept 98
AASERT Reporting Period

NOTE: Grant to which AASERT award is attached is referred to hereafter as "Parent Agreement".

2. Total funding of the Parent Agreement and the number of full-time equivalent graduate students (FTEGS) supported by the Parent Agreement during the 12-month period prior to the AASERT award date.

- a. Funding: \$63,320
- b. Number FTEGS: .50

3. Total funding of the Parent Agreement and the number of FTEGS supported by the Parent Agreement during the current 12-month award.

- a. Funding: \$64,394
- b. Number FTEGS: 1.25

4. Total AASERT funding and the number of FTEGS and undergraduate students (UGS) supported by AASERT funds during the current 12-month reporting period.

- a. Funding: \$91,900
- b. Number FTEGS: 1.0
- c. Number UGS: 0.1

VERIFICATION STATEMENT: I hereby verify that all students supported by the AASERT award are U.S. Citizens.

J. V. Moloney
Principal Investigator

8/28/98
Date

University of Arizona
F49620-95-1-0454